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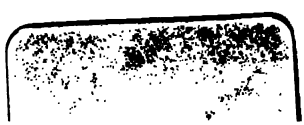
PRACTICAL EXAMPLES IN QUANTITATIVE ANALYSIS

FRANCIS



PRACTICAL EXAMPLES

IN

QUANTITATIVE ANALYSIS.

PRACTICAL EXAMPLES

IN

QUANTITATIVE ANALYSIS

FORMING A CONCISE GUIDE

TO THE

ANALYSIS OF WATER ETC.

BY

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PREFACE.

The author has endeavoured in this work to select such typical examples of quantitative analysis as may prove most useful to the medical student. Special care has been taken to make each of the processes as simple as possible.

The recent sanitary acts have thrown upon the medical profession the responsibility of examining waters chemically with a view of ascertaining their potability and freedom from various organic impurities. The details of water analysis are fully described in the following pages.

Other examples of analysis are given, which the author hopes will furnish such general instructions as will enable the student with a little variation, to apply the examples here given to other cases which, though differing in detail, are the same in principle.

The Author has to acknowledge his obligation to Dr. Ralfe for many important suggestions, and also for the trouble he has bestowed on the revision of the proof sheets.

LONDON. *May*, 1873.

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INTRODUCTION.

A substance present in a mixture may be estimated in three ways.

1. By precipitating, collecting and weighing the precipitate; this is the GRAVIMETRIC METHOD.

2. By precipitating or otherwise altering it with a *solution* of a reagent of known strength, and ascertaining the quantity of the reagent required to effect the complete change; this is the VOLUMETRIC METHOD.

3. The variation and intensity of colour produced by a reagent often affords a ready means of estimating certain substances; this is the COLORIMETRIC METHOD.

In quantitative analysis the French or Metric system of weights and measures is employed. In this system the *gramme* is taken as the *unit of weight*, which represents a cubic centimeter of distilled water, at its greatest density; viz. 4° C.

The *unit of capacity* is the *litre*, which contains 1000 cubic centimeters; consequently a litre of distilled

water weighed at 4° C. should weigh 1000 grammes.

The *multiples of these units* are characterized by Greek prefixes: thus,

Gramme . . .	1·	Litre	1·
Decagramme .	10·	Decalitre . . .	10·
Hectogramme .	100·	Hectolitre . .	100·
Kilogramme .	1000·	Kilolitre . . .	1000·

the unit of each denomination being ten times as great as the preceding one.

The *sub-multiples* of the units are characterized by Latin prefixes; thus,

Milligramme .	·001	Millilitre . . .	·001
Centigramme .	·01	Centilitre. . .	·01
Decigramme .	·10	Decilitre . . .	·10
Gramme . . .	1·	Litre	1·

Here the unit of each denomination is ten times less than the one below it.

MEASURES OF WEIGHT.

(Dr. Warren De La Rue.)

	English grains.	Troy ounces.	Avoirdupois lbs.
Milligramme. . .	0·015432	0·000032	0·0000022
Centigramme . .	0·154323	0·000322	0·0000220
Decigramme . .	1·543235	0·003215	0·0002205
Gramme	15·432349	0·032151	0·0022046
Decagramme . .	154·323488	0·321507	0·0220462
Hectogramme . .	1543·234880	3·215073	0·2204621
Kilogramme . . .	15432·348800	32:150727	2·2046213

Measures of Capacity.

	Cubic inches.	In pints.	In gallons.
Millilitre	0·061027	0·001761	0·00022010
Centilitre	0·610271	0·017608	0·00220097
Decilitre	6·102705	0·176077	0·02200967
Litre	61·027052	1·760773	0·22009668
Decalitre	610·270515	17·607734	2·20096677
Hectolitre . . .	6102·705152	176·077341	22·00966767
Kilolitre	61027·051519	1760·773414	220·09667675

For all practical purposes, however, it is sufficient to remember that

1 gramme = nearly 15·4 grains Eng.
1 kilogramme = ,, 2 lbs. 3 oz. 5 drs.
1 litre = ,, 1 pt. 15 fl. oz. 2 drs.
1 decilitre or 100 C.C.'s = ,, 3 fl. oz. 3 drs.
1 cubic centimeter = ,, 16·3 minims.

CHEMICAL ANALYSIS.

PART I.

GRAVIMETRIC ANALYSIS.

The Balance.

A delicate balance is a chief requisite. One to carry 100 grammes (over 3 ozs.) and when loaded to show quickly the variation of $\frac{1}{2}$ a milligramme ($\frac{1}{100}$ of grain).

Equality in the length of the arms is necessary to ensure delicacy. If the arms be unequal the same weight changed from one pan to the other gives a different result: to detect the defect, weigh something (a bit of metal) in one pan, note the weight, change to the other pan and weigh again. If the fault exists the weight will differ.

The balance is enclosed in a glass case, (Fig. 1.) furnished with spirit levels, regulating screws, and adjustment lever (*d*).

When the balance is at rest or whilst the weights

are being adjusted the instrument is kept at rest by means of the adjustment lever (*d*).

The case must stand on a flat substantial table or support free from vibratory movements. The level is adjusted by the screws, and the spirit levels denote the exact position. The air within the case must be kept dry by the permanent presence of a small beaker $\frac{1}{4}$ full of oil of vitriol, it is usual also to add a vessel containing quick lime or caustic potash to absorb acid gases.

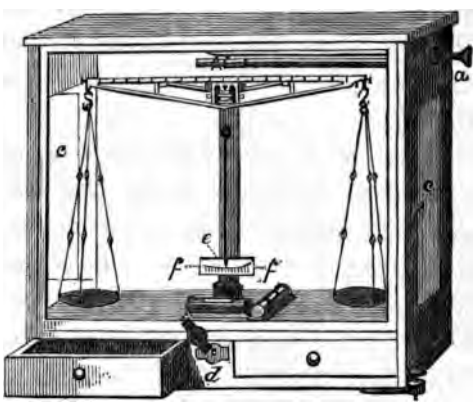

Fig. 1.

The weights. The French system of weights has already been described (Introduction).

The larger weights should be of gilt brass, the smaller of sheet platinum with the corners turned up. The weights must be moved with forceps, *never handled.* They must harmonize with each other *e.g.* the 50 must be exactly equal to those which make up to fifty. Rigorous testing in many combinations should be performed and any found incorrect must be rectified.

The rider. To weigh below ·01 grms. we use the *rider,* this is formed of bent wire capable of being shifted to any of the divisions on the beam which is divided into tenths. The rider being placed on the last or tenth division is equal to ·01 grms. while each division nearer the fulcrum makes a difference in weight of ·001 grm. less. Minute variations of weight are thus discernible and by the division of each degree into halves and quarters extreme accuracy can be obtained. The rider is caught up and moved by a brass rod, worked from the outside of the case (*a*): an inspection of the case will at once show its action.

Weighing. The process of weighing will be best described by an actual example.

Suppose we wish to determine the weight of a platinum basin. We first of all ascertain if the balance is in equilibrium, by liberating the

pans with the screw (*d*) and observing if the pointer (*e*) swings to an equal distance on each side the central mark on the scale (*ff*); if it does not swing to an equal distance but moves to one side more than the other, the balance must be adjusted. A brass arm about 2 inches long fixed to a screw above the fulcrum serves for this purpose. A deflection to either side makes that the heaviest.

The pans are steadied and the basin perfectly cleaned and dried previously in an air bath, is placed in one pan, usually the one on the left hand of the operator, and the weights placed in the other; at first we guess at the probable weight, and place say 50 grammes on this pan; this proves too much for the pointer travels towards the pan supporting the basin. We remove the 50 and try the next highest or 20 grammes; as this is too little we allow it to remain and add the two 10 gramme weights thus making 40 grammes in all. This being still insufficient we add 5 grammes; still too little; allow it to remain and add 2 grammes; too little; add 1 gramme, too much; remove the one gramme weight and try ·5 gramme; too much; try .2 gramme, too little; allow ·2 gramme to remain and add ·1 gramme;

too little; add another ·1 gramme; still too little. As we had previously tried the ·5 gramme weight and found it too heavy we recommence with ·05 gramme, this proving too little is allowed to remain and ·02 gramme added; still too little; ·01 gramme; too much; remove and recommence with rider say on 5; too much; on 3; this is just sufficient, the pointer swings an equal number of degrees on either side of the scale. The weight of the basin is therefore 47·453 grammes.

EXAMPLES OF GRAVIMETRICAL OPERATIONS.

EXAMPLE I.—DETERMINATION OF TOTAL SOLIDS IN POTABLE WATER. (*a*) *Collection of Water.* A Winchester quart bottle (obtainable from any druggist) is the best vessel for collecting and preserving a water for analysis. One that has contained mineral acids is preferable, as a perfect washing with water leaves no doubt of the cleanliness of the interior. The bottle is rinsed out with *the water to be examined,* and then filled with it and stoppered.

(*b.*) *Filtration of the water.* It is best to make

a rule of filtering all waters whether they are turbid or not. A circle of *Swedish* filtering paper is folded across and then across, and fitted to a glass funnel of about 5 or 6 inches in diameter, by opening out one of the sides so as to form a cone, and thoroughly washed with a jet of *distilled water* from a wash bottle. Fig. 2.

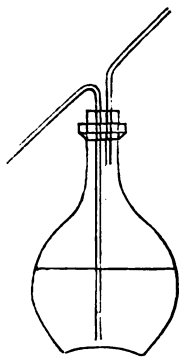

Fig. 2.

The funnel is supported in the neck of another Winchester quart bottle, which has been washed with distilled water, and the filtration proceeded with.

(*c.*) *Weighing the platinum basin.* The method of ascertaining the weight of the basin or capsule has been described under the balance.

(*d.*) *Evaporation.* The weight of the basin having been recorded, 100 C.C. of the water are measured into it from a graduated glass cylinder, Fig. 3, and evaporated over a steam bath.

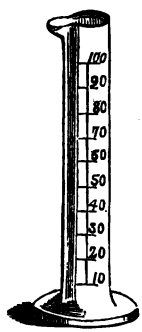

Fig. 3.

For ordinary purposes a cheap and efficient steam bath can be made from a pint oil can, by fitting it with a cork perforated to admit an ordinary glass funnel. The can is partially filled with water and the platinum basin placed in the open part of the funnel, the escape of steam being allowed by a folded piece of paper placed between the edge of the filter and the capsule (Fig. 4); the apparatus is sup-

Fig. 4.

ported on an ordinary retort stand and ebullition maintained over an argand gas lamp placed below.

The evaporation requires about 2 hours. Five or ten minutes must elapse after the water appears dissipated, to allow the residue to become thoroughly dry. The basin is then removed, the bottom wiped quite dry, it is allowed to cool and is then weighed. The difference is usually very small, and varies from ·02 gramme to ·1 gramme. The results are recorded as grains in the gallon or parts in 100,000.

(e) Calculation. The number representing the weight of the residue *multiplied by* 700 gives the number of *grains in a gallon*: multiplied by 1000

gives *parts in* 100,000; for example,

Evaporated 100 C.C. of water = 100 grammes.

Weight of basin and residue	.	47·4850
,, ,, empty	. .	47·4530
		·0320

(i) 0320 x 700 = 21·4 grains per gall.

(ii) 0320 x 1000 = 32·000 parts in 100,000.

EXAMPLE II.—DETERMINATION OF TOTAL SOLIDS IN MILK. Evaporate 5 grms. of milk, in a thin weighed plantinum dish, in a steam bath and place in an air bath, fig. 5, for about 3 hours at a temperature of 100° C. till the weight of the residue becomes constant. The increase of weight above that of the platinum capsule represents the total solids of the milk, which should not fall below 11 per cent; good milk should yield 12—14 per cent.

EXAMPLE III.—ESTIMATION OF CASEIN IN MILK. Place in a weighed platinum dish 5 grammes of fresh milk, and evaporate to dryness over a steam bath and finally dry in an air bath. Ascertain the weight of the residue, add to it $\frac{1}{5}$th its weight of gypsum (calcium sulphate), and triturate the the whole in a mortar. Exhaust the powdered mass with ether and alcohol to remove fatty matters, salts and extractives. The weight of the residue, after subtracting the weight of gypsum

originally added, represents the amount of casein in 5 grammes of milk, and to find the proportion of casein in 100 parts the following calculation must be made $\frac{n \times 100}{5} = x$ the number of grms. in 100 parts of milk; n representing the quantity of casein in 5 grammes of milk.

Cows' milk contains about 4 per cent. of casein; unadulterated milk should not yield less than 3 per cent.

EXAMPLE IV.—DETERMINATION OF TOTAL SOLIDS IN URINE. Measure off 20 C.C. of urine with a pipette* into a porcelain capsule of known weight, which is again weighed to ascertain the weight of the urine. Heat it on the steam bath till all the water is driven off, and the capsule ceases to lose weight, finally dry in an air bath (Fig. 5) to expel

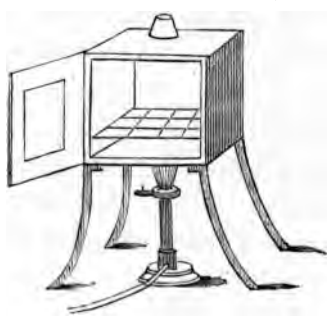

Fig. 5.

* See p. 23.

any last traces of moisture, and again weigh. Suppose the weight of the capsule to be 10 grammes, and the weight of the urine 23 grms., then the united weight is 33 grammes; after evaporation the weight is 10·85 grammes, the residue therefore weighs ·85 gramme, which represents the amount of solids in 20 C.C. of urine. To find the proportion in 1000 parts calculate as follows:

Weight of urine.		Weight after evaporation.		Weight of total solids.
23	:	·85	:: 1000 :	37

EXAMPLE V.—DETERMINATION OF URIC ACID IN URINE. Collect the urine passed in the 24 hours and measure. Take 200 C.C. and add 20 C.C. of strong hydrochloric acid. Set aside in a tall urine-glass for 24 hours to allow the uric acid crystals to separate. Dry a small filter paper in the air bath at 120° C. and weigh. Collect the crystals on this filter and wash them well with water slightly acidulated, using a wash bottle. Dry them with the filter in the air bath and weigh. For example, the weight of the dry filter is 0·27 gramme, with the crystals when dried it weighs ·42 gramme, therefore the weight of the crystals in 200 C.C. of urine will be 0·15 gramme,* and if the

* The crystals are inseparably united with the colouring

quantity of urine passed in 24 hours be 950 C.C.; then,

Quantity of urine taken.		Weight of uric acid in 200 C.C. of urine.				Weight of uric acid in 950 C.C.
200	:	0·15	::	950	:	0·7

EXAMPLE VI.—DETERMINATION OF ALBUMIN IN URINE. Collect the urine for twenty-four hours and measure; introduce 50 C.C. of this urine into a Mohr's burette and allow it to fall, a C.C. at a time, into a porcelain dish containing an ounce of boiling distilled water. If the urine is sufficiently acid of itself no further addition of acid will be required, but if not it will be necessary when all the urine has been passed into the boiling water, to add a drop or two of acetic acid to the mixture, most carefully avoiding excess. When the albumin is completely coagulated, it is allowed to settle at the bottom of the vessel before proceeding to filtration. When the supernatant fluid is quite clear, it is poured upon a weighed filter, the coagulated albumin remaining on the filter whilst the fluid runs through; any particles of albumin adhering to the porcelain dish are to be removed with a feather and placed on the filter. The mass

matters of the urine, which augment their weight. On the other hand a small quantity of uric acid remains unseparated in the urine and counterbalances this excess.

is then well washed with boiling water till the washings give no precipitate with silver nitrate. The filter with the mass is then removed and placed on a watch glass and carefully evaporated in a water bath until it ceases to lose weight. The whole is then carefully weighed, and after deducting the original weight of the filter and watch glass from the total weight, the remainder represents the quantity of albumin in 50 C.C. of urine; and if this quantity be 0·3 grm. and the amount of the twenty-four hours urine 1200 C.C. then $\frac{1200 \times \cdot 3}{50} = 7{\cdot}2$ grms. of albumin in the twenty-four hours urine.

EXAMPLE VII.—SEPARATION OF ORGANIC AND INORGANIC CONSTITUENTS IN DRIED RESIDUES. The dry residue, left after the evaporation of the water, represents the organic and inorganic materials of the mixture. To separate these, the platinum dish supported on a triangle, is heated over a Bunsen's lamp till the ash is of a grey or red colour. The platinum dish is then withdrawn and when cold weighed.* The weight lost

* The dish should be allowed to cool under a glass shade in which is placed some oil of vitriol in a beaker, in order to prevent the absorption of moisture.

by incineration represents the quantity of organic matter in, say 60 grms., of the mixture. And the weight of the residue left after incineration represents the amount of inorganic matters. Thus, if the residue left after the evaporation of 60 grms. of the mixture weighs 13 grms., and after incineration weighs only 5 grms., it is evident that 8 grms. of organic matter have been burnt off, and that 5 grms. and 8 grms. respectively represent the quantity of inorganic and organic principles present in 60 grms. of the mixture. And to find the proportion of these substances in 100 parts it is necessary to calculate as follows:—

Weight of mixture.		Weight after incineration.		Weight of inorganic matter in 100 parts.
60	:	5	: : 100 :	8·3

and

Weight of mixture.		Weight lost by incineration.		Weight of organic matters in 100 parts.
90	:	8	: : 100 :	13·3

The loss of weight which water residues experience on ignition, was formerly used as an indirect estimate of the organic matter; the process having been found fallacious is abandoned in the case of water.

Ex. VIII.—Determination of Specific Gravity. The determination of the specific gravity of many liquids often forms the chief means of ascertain-

ing their purity. Where accuracy is required the density must be determined by actually weighing a given bulk of the liquid measured at the standard temperature. The weight compared with that of an equal quantity of water denotes the specific gravity.

The most convenient quantity of liquid to weigh is 50 C.C. Bottles holding 50 C.C. when filled up to a mark on the neck of the tube, may be obtained at the instrument dealers. A cubic centimetre of water being a gramme, such a bottle holds 50 grammes of water, but more or less of liquid lighter or heavier than water. As liquids expand and contract by alteration of temperature, the measurement of the liquid must be performed at a certain degree. 15° C. is most convenient.

A bottle, Fig. 6, which holds 50 grammes of water when measured at 15° C. having been obtained, the liquid to be examined is poured in, if the temperature is too low it is raised by plunging the bottle into hot water, if too high it is lowered by plunging it into ice water. When the proper degree is obtained we take the weight of the bottle, filled with the liquid; and the weight, after that of the empty bottle is subtracted, multiplied

Fig. 6.

by 2 gives the specific gravity of the liquid in hundreds; for example,

(i.) Oil of Vitriol. Weight of bottle full 105·021

,, ,, empty 10·521

94·500

and 94·500 X 2 = 189 = sp. gr. oil of vitriol.

(ii.) Alcohol. Weight of bottle full 53·021

,, ,, empty 10·521

42·500

and 42·500 × 2 = 85 = sp. grav. of alcohol.

Hydrometers. For rougher estimations of specific gravity spindle-shaped instruments called hydrometers are employed. They are floated in the

liquid, the depth at which they settle denotes the specific gravity, which is recorded by a scale on the stem. Usually two hydrometers are required, one for liquids heavier than water, the other for lighter.

Some are manufactured for particular liquids and designated by special names as *Lactometers*, *Saccharomcters*, *Urinometers*, etc.

Fig. 7.

PART II.

VOLUMETRIC ANALYSIS.

The standard measure used in volumetric analysis, is the cubic centimeter, this being the volume of one gramme of distilled water at 4° C. Instruments for measuring liquids are graduated in cubic centimeters, their multiples and divisions.

Instruments Employed.

Pipettes. Are small spindle-shaped tubular vessels, plain or graduated so as to contain specific quantities of fluid 10, 20, 50 and 100 C.C. Some are made with a bulb and have simply a mark *a-b* on the neck (Fig. 8, A); others are simply cylinders graduated throughout their entire length in C.C.'s (Fig. 8, B).

To use the pipette; the liquid is drawn up by suction till it rises above the mark *a-b*, the moistened forefinger being then pressed over the mouth A, and the pipette withdrawn from the fluid, any fluid adhering to the outside of the instrument must be removed. The forefinger is then partially raised

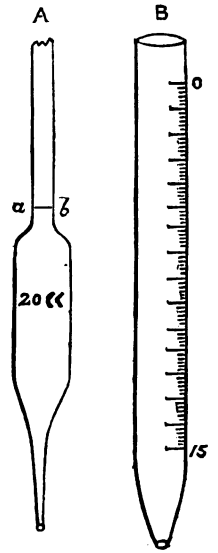

Fig. 8.

and the liquid allowed to sink down to the mark *a-b* and when this point is reached the outflow is arrested by replacing the finger; the liquid can then be conveyed where it is required.

Beakers. Are small glass vessels useful for holding the fluids into which the test liquids are dropped. They are of various sizes, from 8 to 12 ozs. capacity being most convenient, their usua form is represented at *c* in Fig. 9.

BURETTES. Are graduated tubes of different forms; the most useful is Mohr's and that only will

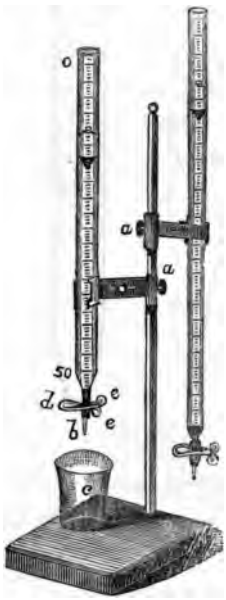

Fig. 9.

A burette stand holding two burettes, fitted with india-rubber tubing, glass jet, and pinchcock. Each burette contains an Erdmann's float for marking the level of the liquid in the burette.

be described. It consists of a straight tube 15 to 18 inches long and $\frac{1}{2}$ to $\frac{3}{4}$ in diameter, drawn to a point at its lower end and to which is affixed by means of caoutchouc tubing a fine glass jet (*b.*) A clamp or pinch cock (*e, d*), which closes the tubing, prevents the escape of fluid till the buttons *e e* are compressed. It is easy with this contrivance to allow a stream or only drops to pass.

The tube is graduated into cubic centimeters which may be again subdivided into $\frac{1}{5}$ and $\frac{1}{10}$. The scale commences at 0° near the top and is continued downwards.

The burette is supported on a wooden stand fitted with moveable supports *aa.* Fig. 9.

In filling the burette, care must be taken to see the pinchcock is properly adjusted, and then the liquid may be poured in through a funnel until the liquid rises above 0°, the pinchcock should then be sharply pressed, so that a good stream may run out and fill the jet and flexible tube till the level of the liquid stands exactly at 0°. The instrument is now ready for use.

In measuring fluids with pipettes and burettes care should be taken that the reading should be made from the *under border of the dark zone* as shown in Fig. 10, this dark border can be better observ-

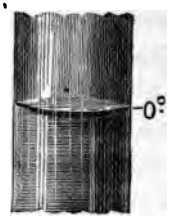

Fig. 10.

ed if a sheet of white paper be placed behind the burette.

In cases where great accuracy is required an instrument called Erdmann's float is employed. It is constructed of a length of glass tube closed at both ends and of just sufficient size to fit the burette. The lower part is narrowed and contains a little mercury to enable the instrument to float perpendicularly on the surface of the liquid. A well marked line is drawn round the circumference and this line is made coincident with the first mark on the burette and the movement of the line downward is then regarded instead of the surface of the liquid as the latter is drawn out.

The burette being charged, and the fluid for examination measured off by the pipette into a beaker, we proceed to make the experiment as follows. By pressing the pinchcock a few drops are allowed to run from the burette into the fluid in the bea-

ker and the mixture is well stirred, and so on. The fluid is cautiously added till some decided reaction is produced, such as change of colour, a precipitate, or reaction with test paper. When the process is complete the number of C.C.'s required to effect the reaction is read off and the estimation made as in the following examples.

VOLUMETRIC EXAMPLES.

EXAMPLE I.—ESTIMATION OF CHLORINE AS CHLORIDES IN WATER. Much chlorine in inland water from wells is pretty clearly indicative of sewage contamination. It can be estimated with solution of nitrate of silver of known strength.

Crushed crystals of nitrate of silver are dried in a basin for half an hour on the steam bath. ·479 grammes are weighed in a beaker of which the weight has been taken. Distilled water is added to dissolve the crystals and the solution is poured into a litre flask. The beaker having been washed out into the flask several times the solution is made up with distilled water to a litre and bottled. The operation must be done very carefully to avoid the least error. Each cubic centimeter of this solution

is equal to ·0001 gramme (= $\frac{1}{10}$ milligramme) of chlorine.

Besides this solution a strong neutral solution of yellow chromate of potash is required.

Process. A 50 C.C. burette is washed out with a little of the silver solution and then filled, with the precautions already stated. 100 C.C. of the water are measured into a beaker capable of holding about five times as much, together with two or three drops of the chromate or sufficient to develope a decided yellow tint.

The silver solution is added cautiously from the burette. The water gets milky owing to precipitation of chloride of silver. This is white but appears yellow from the colour of the liquid. The moment all the chlorine is precipitated *chromate* of silver is formed. Chromate of silver is dark red. Directly therefore the first faint tinge of red is discernable and remains permanent on stirring, the addition of the silver solution is discontinued. The number of cubic centimeters used indicate the number $\frac{1}{10000}$ of gramme of chlorine in the 100 C.C. of water. These may be converted into grains in gallon or parts in 100,000 by multiplying respectively by 700 or 1000.

Example:—100 C.C. of water require 15 C.C. of

silver solution then 100 C.C. of water contain 1·5 milligrammes or $\frac{15}{10000}$ gramme of chlorine = ·0015 grammes.

∴ ·0015 X 700 = 1·05 grains in Gallon.

·0015 X 1000 = 1·50 parts in 100,000.

The operator should stop at the first tinge of red and not add the silver solution until a full red is developed or the results will be too high. It is easy to hit the precise point with a little practice. The chromate should be tested in distilled water to ascertain its freedom from chlorides. ($\frac{1}{10}$ of a C.C. of silver solution should produce a distinct red colour.)

With much chlorides it happens that the turbidity of the water masks the red colour when it is produced. When more than 30 C.C. of silver solution are required the water should be diluted to four times its bulk with distilled water and the process re-performed.

The quantity of chlorine in an ordinary good river water is under a grain per gallon.

	Grains per gallon.	Parts in 100,000
Bala Lake	·706	1·009
Thames (Kew)	·847	1·210
Thames (London Bridge)	4·452	6·360
Well in Village. (*E. of* London.)	15·61	22·3

EXAMPLE II.—ESTIMATION OF THE HARDNESS OF WATER. The so-called "hardness" of water is due to mineral salts, mainly carbonates and sulphates of calcium and magnesium. The Carbonates are precipitated by boiling the water, the hardness due to them is therefore called *temporary*. The sulphates are not precipitated by boiling and form *permanent* hardness.

The chief feature of hard water is its power of destroying soap, forming a disagreeable curd and rendering a lather impossible until the water is softened.

A plan of estimating hardness was founded on this property by Dr. Clark.

A measured quantity of water is shaken with a soap solution of known strength, and the degree of hardness inferred from the quantity of soap solution used to form a permanent lather. The process applied to the unboiled water gives the *total hardness;* to the water after boiling the *permanent hardness;* the difference between the results represents the *temporary* hardness.

The hardness is represented by degrees, each degree being equal to one grain of calcium carbonate in a gallon.

The solutions required for the process are an

alcoholic solution of soap and an artificial water of standard hardness with which to fix its strength. The latter should contain the equivalent of 16 grains of calcium carbonate in a gallon of distilled water and is made thus :—

Powdered white marble, or what is better, pure precipitated calcium carbonate, is dried in a basin on the steam bath. 1·6 grammes are then weighed out in a beaker (about 3 ounces capacity) the exact weight of which has been previously ascertained. About half an ounce of water is added, and then moderately strong hydrochloric acid little by little until solution is effected. A concave glass disc, watch or clock glass, must cover the beaker and be just slipped aside for the addition of acid and immediately replaced to prevent loss during effervescence. When solution is complete the liquid must be poured down a glass rod into a porcelain basin ; the beaker and watch glass washed once or twice with a stream of water blown from a wash-bottle, care being taken to avoid splashing, and the washings added to the rest. The basin is then placed in the water bath and its contents evaporated to dryness with subsequent prolonged heating to effect the removal of last traces of acid, and as further precaution, suc-

cessively moistened with water and evaporated once or twice. Finally the residue is again dissolved in about 100 C.C. of water, poured down a glass rod into the litre measuring flask, the basin washed out once or twice into the flask, and the whole made up to the litre. When required for use this solution diluted to seven times its bulk with water, forms a water of exactly 16° of hardness, that is, it contains the equivalent of 16 grains of calcium carbonate in a gallon. The accuracy of the results obtained, however, depends on the care bestowed in the process; so every precaution must be taken to avoid error.

To prepare the alcoholic solution of soap, either soda or potash soap may be used. Preference is often given to the latter, as its solution is said to be more stable than the other, but the former is more conveniently prepared. About 7 grammes of fine shavings of good curd soap are dissolved in a litre of *proof* spirit, applying heat if necessary, filtering the solution, and subsequently adding 100 C.C. more spirit.

For the potash soap about 20 grammes of lead plaster and 10 grammes of carbonate of potassium are ground together in a mortar and extracted repeatedly with hot proof spirit, filtered, and made up to a 1100 C.C.

To standardize this soap test fill a 25-C.C. burette with it. Introduce 10 C.C. of the calcium solution measured accurately with a 10 C.C. pipette, and 60 C.C. of distilled water into a 6-ounce stoppered bottle. Run the soap solution into the bottle a cubic centimeter or so at a time and shake the mixture between each addition: when lather begins to form add the soap very cautiously even drop by drop, shaking as before. Stop the addition the moment a lather can be produced which lasts for ten minutes without breaking in continuity. Observe the number of C.C. of soap test employed and calculate how far it must be diluted with more spirit so that exactly 17 C.C. shall produce the lather in a fresh portion of lime solution.

To calculate what dilution the litre will require to be of the standard strength. Multiply 17 by 1000 and divide by the number of C.C. found; *for example,* 14 C.C. of soap test are required to produce a lather in the trial expt. then $\frac{1700}{14} = 121{\cdot}428$.

Therefore a litre of soap test must be diluted to 121·428 C.C. with more spirit. The calculations can then be corroborated with another trial.

If more or less than 17 C.C. is then required

fresh corrections must be made and so on until the requisite strength is exactly established.

The details of the estimation of hardness in a sample of water differ very slightly from those already given. 70 C.C. of the water placed in the 6-oz. bottle are shaken with successive quantities of the standardized soap solution, until the lather is formed lasting the required time. Ascertaining the quantities of soap test used, the hardness is then determined by the following table:—

Degrees of Hardness grains of $CaCO_3$ in gallon.	Soap Solution in cubic centimeters.	Degrees of Hardness grains in $CaCO_3$ in gallon.	Soap Solution in cubic centimeters.
0	1	9	10
1	2	10	11
2	3	11	12
3	4	12	13
4	5	13	14
5	6	14	15
6	7	15	16
7	8	16	17
8	9		

EXAMPLES OF HARDNESS FOUND IN WATER.

Thames . .	14°
New River . .	15·6
Chalk Spring .	17·28

Permanent and Temporary hardness. The result obtained from normal water represents the total hardness. It is usual to determine the permanent hardness after boiling the water for one hour in a flask taking care to make up any loss by evaporation with distilled water. This loss however can be reduced to a minimum by fitting the flask with a perforated cork in which is inserted a tube $\frac{3}{8}$ inch in diameter and 6 feet long; if the water be kept simmering the steam will condense by passing through the length of the tube, and return to the flask. The boiled water should then be filtered and the hardness determined, after cooling it.

The difference between the permanent hardness and total hardness represents the temporary hardness.

EXAMPLE III.—ESTIMATION OF UREA IN URINE. When mercuric nitrate is added to a solution of urea an insoluble compound of urea and mercuric nitrate is formed; upon the formation of this precipitate the means of estimating urea in solution is based.

The following solutions are required.

1. *A standard solution of mercuric nitrate,* which is thus prepared. Dissolve 77·2 grms. of pure, dry mercuric oxide in strong nitric acid, evaporate the

solution to the consistence of a syrup and dilute up to 1 litre with distilled water. If a yellow precipitate is produced by dilution, too little acid is present. It must be evaporated down, and a fresh quantity of acid added and again diluted. 1 C.C. of this solution corresponds to 0·01 grm. of urea.

A solution of Barium hydrate and nitrate, prepared by mixing 1 part of cold saturated solution of barium nitrate with 2 parts of a cold saturated solution of barium hydrate, and then adding 3 parts of distilled water.

3. *Soda test paper*, dip a sheet of white blotting paper into a concentrated solution of sodium carbonate and dry.

Process. The urine* passed during the 24 hours is collected and carefully measured; of this 20 C.C. are removed by means of a pipette capable of holding that quantity, placed in a small beaker, and 20 C.C. of the barium solution added; the phosphates and sulphates being thus precipitated are removed by filtration. Of the filtrate 20 C.C.

* If the urine contain albumin this must be coagulated, by placing 2 ounces of urine in a small 2-ounce flask plunged in boiling water, when the albumin is quite coagulated it is filtered off, and the filtrate allowed to cool, when it can be used.

which contains 10 C.C. of urine are measured off with a pipette into a beaker, a drop or so of silver nitrate may be added to precipitate any excess of chlorides, and the beaker is then placed beneath the burette, which has been filled with the standard solution of mercuric nitrate, the pinchcock is compressed and a few C.C.'s allowed to fall into the beaker, the mixture is well stirred and a drop removed with a glass rod and allowed to fall on the soda test paper, if no yellow stain appears the addition is continued till one becomes visible, when the process is complete. The calculation is made as follows; suppose the urine passed in the 24 hours amounted to 1260 C.C., and 17 C.C. of mercuric solution have been used to precipitate 10 C.C. of urine, each C.C. of the solution being equivalent to 0·01 grm. of urea; then $\frac{1260 \times 17}{10} = 21{\cdot}4$ grammes of urea passed in the 24 hours.

Example IV.—Estimation of Sugar. When an alkaline solution of *cupric* sulphate is boiled with a solution of sugar, the salt is reduced and a red precipitate of *cuprous* oxide is thrown down. This reduction of cupric salts, furnishes a method for estimating the amount of sugar in solution.

The following solutions are required.

(1.) *The copper solution.* Dissolve 34·63 grms. of crystallized cupric sulphate in distilled water, and make up to 1 litre. 1 C.C. of this solution corresponds to 0·005 grm. of sugar.

(2.) *The Alkaline Tartrate solution.* 173 grms. of sodium and potassium tartrate (Rochelle salt) and 80 grms. of potassium hydrate are dissolved in water to the measure of 1 litre. 10 C.C. of this solution are to be used with every 10 C.C. of the cupric solution.

(A.) *Estimation of sugar in urine.* The urine passed during the 24 hours is collected and carefully measured. Of this urine measure off 10 C.C. with a pipette, and dilute with distilled water to 200 C.C. and fill a burette with a portion of diluted urine.

Into a porcelain basin containing 50 C.C. of distilled water, measure off 10 C.C. of standard copper solution and 10 C.C. of alkaline tartrate solution, and boil the mixture.

When the alkaline copper solution has reached the boiling point a few drops of the dilute urine are run into it from the burette; at first the addition only makes the copper solution turbid with a greenish-red precipitate, which subsequently on the further addition of urine acquires a deeper red

and settles readily at the bottom of the porcelain vessel. After each addition of urine the precipitate should be allowed to settle and the vessel slightly tilted so as to observe the colour of the supernatant fluid, when this becomes perfectly colourless the process is complete and the estimation can be made as follows; suppose the patient passes 4110 C.C. of urine in the 24 hours and 30 C.C. of dilute urine are required to reduce the copper solution, then 4110 C.C. ÷ 30 gives the quantity of sugar in the 24 hours urine.

(B.) *Quantitative estimation of sugar in Milk.* Curdle, say 100 C.C. of fresh milk and remove the curds by filtration. Dilute 10 C.C. of the filtrate with distilled water to the volume of 200 C.C. and with this fill a Mohr's burette; for the remainder of the process proceed as directed in the quantitative estimation of sugar in urine.

EXAMPLE V.—ESTIMATION OF CREAM IN MILK. Take a tall glass cylinder as represented in fig. 11 graduated into 100 volumes, and fill it with new milk, after a time the cream rises to the surface and the amount formed can be read off in percentages.

Cream is formed of the fatty matters of milk mixed with casein, milk sugar, and milk salts.

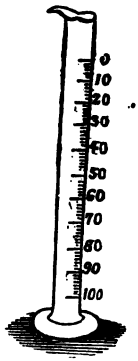

Fig. 11.

Unadulterated milk should never yield less than 5 per cent. of cream.

PART III.

COLORIMETRIC ESTIMATION.

The intensity of a colour, produced in a liquid with some reagent, often affords a delicate method of ascertaining the quantity of a given substance in that liquid.

The best process for estimating small quantities of ammonia is of this nature, and has been successfully applied by Messrs. Wanklyn and Chapman to the estimation of the organic impurities as well as the nitrates and nitrites present in water.

The method is briefly as follows :—The water is acted on with reagents capable of converting the nitrogen of the various impurities into ammonia. The water being then distilled, the ammonia comes over in the distillate and is received in a cylindrical glass vessel, and the quantity of ammonia is then estimated by comparing the colour produced by a few drops of the solution known as Nessler Test with that given by a solution of ammonia of known strength.

Before entering upon the details of the process it is necessary to describe the process of distilla-

tion as well as the preparation of Nessler Test and standard ammonia.

DISTILLATION. The chief requisite for distillation consists of a flask or stoppered retort *a* capable of holding 1 litre. This is fitted to an apparatus for condensing the vapour produced during distillation. The most efficient is the condenser introduced by Liebig (hence called Liebig's condenser) and should be of glass. It consists of a tube *b c* ½ inch in diameter fitted into an outer tube *d e* about 2 feet long by perforated corks fitted tightly to the ends. This outer tube has two bent lateral tubes *f f*. The lower is connected by caoutchouc tubing to a supply of water from a tap, while the up-

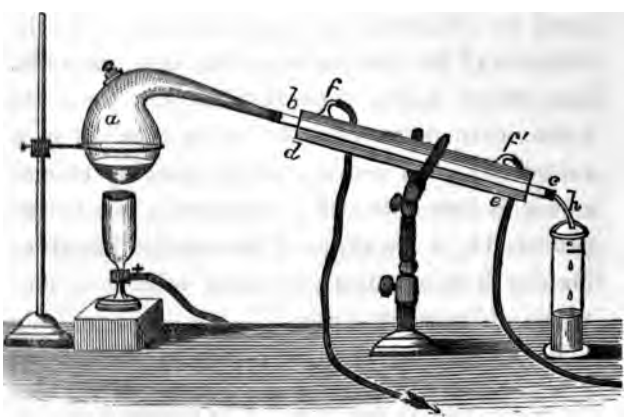

Fig. 12.

per leads to a sink. By this means a supply of cold water which is kept flowing through the outer tube, condenses the vapour passing through the inner one.

The retort may be connected with the condenser by a piece of caoutchouc tubing, or if the openings be very disproportionate by a perforated india rubber cork.

A Bunsen's burner is generally used by experienced chemists for the distillation of water, but an argand lamp with a copper chimney though slower is on the whole safer. The flame of the latter must not be allowed to touch the retort. The Bunsen burner on the contrary is raised so that the flame is spread out against the bottom of the retort.

The distillate or condensed vapour flows by a bent tube *h* into a tall cylindrical glass.

Before using the apparatus for the analysis of water it is necessary to see that it is not contaminated with ammonia. It is therefore requisite to distil water through it for some time till the distillate gives no reaction with Nessler's test.

Nessler Test for Ammonia.* Dissolve 50 grms. of potassium iodide in a small quantity of distilled

* Potassio-mercuric iodide $2(2KI.HgI_2)$.

water, (about 50 C.C.) Place the basin containing this solution on the water bath and add to it a saturated solution of corrosive sublimate. This will cause a red precipitate that disappears on stirring the mixture. Add the mercury solution carefully so as to dissolve the precipitate as fast as it forms. After adding the mercury for some time a point is reached when the precipitate ceases to disappear. When this occurs the liquid must be filtered. To the filtrate 150 grammes of caustic soda in aqueous solution must be added.

After adding the alkali, dilute the mixture to the volume of 1 litre. Add a further 5 C.C. of mercury solution and allow the precipitate to subside for 24 hours.

Decant the clear liquid, and as the liquid is rendered turbid by undue exposure to air a small bottle only should be filled for present use, while the remainder is kept tightly stoppered in a large stock bottle. With this precaution, the test improves in delicacy with age. (Wanklyn and Chapman *Water Analysis*, p. 46.)

The Standard Solution of Ammonia. Crystals of pure ammonium sulphate are crushed and dried between folds of filter paper or by heating in a basin on the water bath. 0·3882 grammes are weighed

out in a beaker, water added to dissolve them and the solution made up to a litre. When required for use 100 C.C. must be taken and diluted to a litre. Each cubic centimeter of the diluted solution should then contain the $\frac{1}{100}$ of a milligramme of ammonia (represented by ·00001 gramme.)

The distilled water required for diluting the standard ammonia solution, must be free from ammonia.

It may be obtained by employing a clean still and rejecting the first and last portion of the distillate, reserving the middle portion only for use.

A cheap and convenient still, for the preparation of distilled water in large quantities, can be made from a two-gallon tin can which serves as a retort, this is connected by india-rubber tubing with a condenser made of tin plate and fitted with an inner glass tube, a constant flow of cold water is maintained by india-rubber tubing connected with water tap and sink.

It is always better to make than buy distilled water, but if bought it must be strictly tested. I have found that when freshly prepared it contains ammonia, but when old it often becomes free from it.

The solutions being prepared, the student should gain some experience, by practice, of the quantity of ammonia corresponding to given shades.

In a series of tall glass cylinders capable of holding 100 C.C. and standing on a sheet of white paper, place respectively 1, 2, 3, 4, 5, etc., C.C.'s of standard ammonia solution and dilute each to 100 C.C. with distilled water, now add 1½ C.C. of Nessler's test from a pipette and note by looking down the tubes the different shade of colour produced in each cylinder, after standing ten minutes. A little practice soon educates the eye to recognise minute differences in colour.

EXAMPLE I.—ESTIMATION OF NITRATES AND NITRITES IN POTABLE WATER. A *Bohemian* glass flask of about 300 C.C. capacity is fitted with a half inch bent glass tube and india-rubber cork, and joined to the condenser with vulcanized tubing.

The condenser and flask having been cleaned, 100 C.C. of the water are introduced into the latter and a mark is made with ink on the outside of the flask at the height the water reaches.

50 C.C. of a solution of caustic soda* containing 100 grammes in a litre is then added.

The flask is heated over a lamp until 50 C.C. have boiled away, that is till the contents are reduced to the mark made on the outside. All the free ammonia which exists in the water is thus driven off.

When cool a piece of metallic aluminium in the form of a thin sheet (·5 to 1 gramme) is introduced, the mouth of the flask is covered with a piece of blotting paper and the whole left undisturbed for several hours or until the aluminium is dissolved.

The nitrates and nitrites are thus converted into *ammonia* by the nascent hydrogen liberated by the dissolving aluminium.

The ammonia is estimated as follows :—

The flask is again fitted to the condenser and the contents distilled, a few pieces of tobacco pipe previously heated to redness being placed in the flask to prevent bumping. The distillate is received into 100 C.C. of pure water, contained in a

* A blank experiment must be performed with the soda solution and pure distilled water to determine the freedom of the former from nitrate. Should nitrates be present they may be destroyed by dissolving aluminium in the soda solution then boiling until the ammonia produced is dissipated.

clean beaker, and beneath the surface of which the end of the condenser must just dip. From 50 to 70 C.C. should be distilled off. The contents of the beaker are then made up to 200 C.C. 100 C.C. are placed in a tall cylindrical glass and the quantity of ammonia estimated with the Nessler solution.

It occasionally happens that in the case of bad waters the quantity of ammonia produced from the nitrates is so great that a *precipitate* is produced in the distillate by the addition of Nessler test. When this happens the remaining 100 C.C. must be diluted with 3 or 4 times its bulk of pure distilled water and the estimation reconducted with 100 C.C. of the diluted portion. This should be done when the ammonia in a 100 C.C. of the distillate more than equals 30 C.C. of the standard ammonia solution.

The presence of nitric acid in water although in itself harmless is in most cases indicative of old contamination and shows organic nitrogen in its most completely oxidised form.

However, as many good waters especially those derived from chalky soils contain nitric acid; a water therefore must not be condemned for containing nitrates unless recent contamination is

proved by an excessive yield of albuminoid and ureal ammonia.

Calculation. The quantity of nitrogen* existing in the water as nitric and nitrous acid can easily be found from the amount of standard ammonia corresponding with that obtained from the water. An example will make the calculation clear.

100 C.C. of the water are treated with alkaline solution and aluminium and distilled into 100 C.C. of pure water.

200 C.C. of distillate are thus obtained and contain, as ammonia, all the nitrogen which originally existed as *nitric* and *nitrous* acid.

Each 100 of the distillate yields a colour equal to 15 C.C. of standard NH_3.

Therefore the 200 C.C. = 30 C.C. of standard ammonia; this 30 C.C. represents the ammonia yielded by the original 100 C.C. of water or 300 C.C. from 1000 C.C. or a litre of water; and as each cubic centimeter of standard ammonia contains ·0001 gramme of ammonia. The litre would yield 300 × ·0001 = ·003 gramme.

Knowing the weight yielded by a litre, and multiplying that with 70 we get the number of

* 14 parts of nitrogen and 17 parts of ammonia correspond to 63 parts of nitric acid.

grains in a gallon, and multiplying with 100 gives parts in 100,000; thus,

·003 × 70 = ·21 grains of ammonia in gallon.

·003 × 100 = ·3 parts in 100,000.

Then to convert the ammonia into nitrogen the following proportion is used.

Ammonia.		Nitrogen.	Ammonia found.	Nitrogen required.
17	:	14 ::	*a*	*x*

Example II.—Determination of Albuminoid and Ureal Ammonia. Half a litre of water, previously filtered, measured with a flask provided for the purpose, is introduced with a funnel into the retort and 15 cubic centimeters of a 10 per cent. solution of sodium carbonate added.*

The retort is connected with a clean condenser and 200 C.C. of water are distilled off, placed in a clean covered flask or beaker and labelled *ureal ammonia.*

The lamp is then removed and 50 C.C. of alkaline solution of potassium permanganate† introduced into the retort.

* *The soda solution* is prepared by dissolving 100 grammes of sodium carbonate in about a litre of distilled water, boiled for 2 or 3 hours, made up to 1 litre and bottled. Care must be taken that the solution does not contract impurity, if it does it must be reboiled.

† *The permanganate solution*, is made by dissolving 8 grm

After the addition of the permanganate solution the lamp is replaced and the distillation proceeded with till 200 C.C. are again obtained. This distillate is placed in a covered beaker or flask and labelled *albuminoid ammonia*. Any bumping during the distillation may be prevented by introducing a few fragments of purified tobacco pipe.

The explanation of the process is this. The organic impurities in water are supposed to be of two kinds. Those which approach *urea* and those which approach *albumin* in nature. The former are of simple constitution and are ultimate oxidized products, the latter complex and are unoxidized or partially oxidized products. Water which has been contaminated may contain either or both. If the contamination is of old standing and the water has been well aërated the ureal class predominates and *vice versa*.

The *ureal* products consist of urea and ammonia; ammonia being a product of even a later stage of oxidation than urea. By the first distillation with sodium carbonate the ureal class is converted into am-

of permanganate and 200 caustic soda (not carbonate) in a litre of pure water. Boil for 3 or 4 hours, in a flask with pieces of ignited tobacco pipe fill up to a litre and preserve in a clean bottle.

monia; this together with that which is free comes over and is secured in the first portion of the distillate.

The permanganate solution being a powerful oxidizing agent quickly oxidizes the *albuminoid* bodies until their nitrogen becomes converted into ammonia, and this is obtained in the second distillate.

By estimating and comparing the relative quantities of ammonia which are produced in each stage we have not only a measure of the total organic impurity but we can judge in what state it exists and how far oxidation has proceeded in purification. For it is hardly necessary to repeat that aëration is the natural provision for the purification of water and that putrescent matter speedily becomes inert in such as has free access to air.

The ammonia in each distillate is estimated by the depth of colour, produced when $1\frac{1}{2}$ C.C. of Nessler's test is added to 100 C.C. placed in a tall cylindrical glass standing on a sheet of white paper, as compared with the colour given by a solution of ammonia of known strength.

Calculation. The calculations required to arrive at the quantity of ammonia yielded by the ureal and albuminoid impurities in a water do not ma-

terially differ from those which have been already given under *nitrates*. The conception may be aided by an example.

½ litre of water used.

Distillate I. With sodium carbonate amounts to 200 C.C.

100 C.C. of this contains ammonia equal to 5 C.C. of standard ammonia solution.

$= \cdot00001 \times 5 = \cdot00005$ gramme of NH_3

$\therefore$ 200 C.C. $= \cdot00005 \times 2 = \cdot0001$ .. ..

The ammonia in the 200 C.C. or ·0001 gramme represents that obtained from a half litre of water. Twice this quantity or ·0002 is contained in a litre; and

Ureal ammonia.

$\cdot0002 \times 70 = \cdot014$ grains in gallon.

$\cdot0002 \times 100 = \cdot02$ parts per 100,000.

Distillate II. With alkaline permanganate solution amounts to 200 C.C.

100 C.C. of this contains ammonia equal to 6 C.C. of standard ammonia solution.

$= \cdot00001 \times 6 = \cdot00006$ grammes of NH_3

$\therefore$ 200 C.C. $= \cdot00006 \times 2 = \cdot00012$.

The ammonia in the 200 C.C. or ·00012 gramme represents that obtained from ½ litre of water.

Twice this quantity or ·00024 is contained in a litre; and

Albuminoid ammonia.

·00024 X 70 = ·0168 grains in gallon.

·00024 X 100 = ·024 parts in 100,000.

The quantities of ammonia which make the difference between a good and bad water, are in themselves so minute, and ammonia is such a common impurity found everywhere, that, we cannot impress too much on the operator the necessity of the utmost cleanliness of apparatus, and purity of reagent, for the successful performance of the foregoing processes.

It is a very easy matter to add double or triple the quantity of ammonia to a water by pouring it into a bottle which was not previously cleaned with distilled water, or by using a condenser that has not had water distilled through it.

APPENDIX.

TABLES OF IMPURITIES FOUND IN VARIOUS WATERS (REPRESENTED IN GRAINS PER GALLON).

	BALA LAKE.	NEW RIVER CO.	THAMES WATER CO.
Total Solids	1·95	20·1	21·6
Total Hardness	·28	15·5	14·0
Chlorine	·706	·72	·80
Nitrogen as Nitrates	·00	·253	·24
Ammonia. Free and Ureal	·0007	·0005	·0007
Albuminoid	·0010	·004	·0045

The above waters although derived from very different sources, present a great similarity in the quantity of ammonia, nitrates, and chlorine, and may serve as standards of comparison of ordinary good potable waters with respect to these impurities. The Bala Lake water is remarkable for its softness, and this in a measure unfits it for drinking purposes, as experience shows that a certain amount of inorganic salts in water, are necessary for health.

TABLES OF ORGANIC AMMONIA, NITRATES, AND CHLORINE FOUND IN GOOD AND BAD WATERS; IN GRAINS PER GALLON.

GOOD WATERS.

	Ammonia. Free or Ureal.	Albumenoid.
Thames from Water Companies	from ·0007 to ·0009	from ·002 to ·010
Manchester Water supply	from ·00042 to ·00098	from ·0045 to ·007
Edinburgh Water supply	from ·000 to ·0009	from ·0023 to ·0056
Loch Katrine, Glasgow	·00028	·0056

River water supplied by Companies for drinking purposes should not yield on the average more than ·0009 gramme of ureal nor more than ·007 gramme albumenoid ammonia.

BAD WATERS.

	Ammonia. Free or Ureal.	Albumenoid.
From Great St. Helen's pump, London	·262	·0126
Pump in Bishopsgate St. London	·525	·0178
Pump in Drapers Hall London	·420	·022
Thames. London Bridge after filtration	·1232	·0245
Water from well in village east of London	2·8000	·21
Well, Nutfield, Surrey	·084	·009
Well, Whitchurch, Hants	·025	·023
River ,, ,,	·028	·07

Good Waters.

	Nitrogen as nitrates and nitrites.
Thames delivered in London. . .	·242
New River Co.	·253
Kent Co.	·256
South Essex Co. (chalk water) . .	·594
Loch Katrine	·021
Bala Lake	nil

	Chlorine.
Bala Lake	·706
Thames at Kew	·847
Thames from Water Co. . . .	·52
Ullswater Lake	·693

Bad Waters.

	Nitrogen as nitrates and nitrites.
Well water from Leyland, Lancashire	1·726
Well water from Whitchurch, Hants .	1·121
Well water from Nutfield, Surrey .	2·820

	Chlorine.
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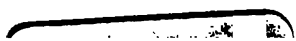
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